ric mode is still active, the process returns to step **484** to sense the current position of the user object.

It should be noted that steps **488, 490,** and **492** can each be performed independently of each other, since each step only requires the deviation data of step **486** to be performed. Thus, steps **488, 490** and **492** can be performed in any desired order, or, preferably, substantially simultaneously.

FIG. **16** is a flow diagram illustrating step **490** of FIG. **15**, in which a resistive output force is applied to the user object **12**. The process begins at **500**, and in step **502**, a restoring force is determined based on the deviation found in step **486** and any other applicable conditions. In the described embodiment, a restoring force is applied to the user object. A restoring force is a linear force vs. displacement relationship **516** and is shown in FIG. **16a**. The restoring force increases in magnitude the further the object is moved from the local origin O, and is applied in a direction opposing the deviation of the user object from the local origin. A restoring force can be described as a "spring return", since it feels to the user as if a strong spring resists displacement of the user object. The restoring force provides a return sensation that forces or "restores" the user object to the local origin O. In the described example, the restoring force can be modeled using Hooke's Law, where resistance force F is proportional to the displacement or deviation d, such that:

$$F=k*d \qquad (1)$$

where d is the deviation along an axis or degree of freedom (−d indicates an opposite direction to +d) and k is a spring constant defining the magnitude of force. In other embodiments, a spring restoring force can be modelled with an exponential stiffness or other relationship rather than the linear stiffness of Equation (1). Also, as shown in FIG. **16a**, a saturation region **518** can be provided, where the magnitude of force generally remains constant when the user object is moved past a particular distance D. Positive and/or negative saturation regions can be defined for each degree of freedom. In some embodiments, the saturation force magnitude is can be limited to a predetermined percentage of the maximum possible output force in a the selected degree of freedom, so that overlay forces can be overlaid on top of the restoring force sensation (or, impulse shaping can perform this limiting function, as described in co-pending application Ser. No. 08/747,844, filed Nov. 13, 1996 by Rosenberg et al. and incorporated by reference herein).

For example, FIG. **16b** is a schematic diagram illustrating the forces on user object **12** in the button mode control (cursor-less) embodiment described above. Once the mode button is pressed and held down, isometric mode is active. The user object **12** then is provided with a local origin O and a four-way restoring force, indicated by the spring schematics **520**. Thus, as long as the button is held by the user and isometric mode is active, the user object will be forced toward the origin position O by simulated springs **520**. In other embodiments, isometric mode can be toggled by a button click, so that the button need not be held to maintain isometric mode. Also, different numbers of springs **520** can be simulated; for example, restoring forces might only be applied in the up and down directions. In the graphical object embodiment, typically one spring **520** is provided perpendicular to the surface **358** into which the cursor **306** is moved. The diagram of FIG. **16b** assumes a user object having 2 degrees of freedom; the diagram can be, for example, a "cube" of springs in 3 degree of freedom embodiment, a line of springs in a 1 degree of freedom embodiment, etc.

Other characteristics or conditions can also affect the magnitude and/or direction of the restoring force. For example, the magnitude of the restoring force F can be changed by altering the spring constant k. For example, a different k can be used in each two available isometric modes. If isometric mode #1 is active from a press of button #1 on puck **22**, a large k can be used to calculate F, thus providing the user with a large restoring force. A large restoring force opposes the user's motion more strongly in less distance d, and thus provides a coarse degree of control over an isometric function such as the speed of scrolling text. In contrast, if an isometric mode #2 is active from button #2 on the puck **22**, a smaller k can be used, thus providing a smaller restoring force and a finer degree of control over an isometric function.

In the graphical mode control embodiments, k can be varied for different graphical objects or surfaces engaged by the cursor. For example, a surface **358** of one graphical object might be associated with a large k and coarse isometric input, and a surface **358** of a different object might be associated with a smaller k and fine isometric input. Alternatively, a graphical object or button associated with an isometric function such as scrolling text might have one k, while a graphical object or button associated with a different isometric function such as panning or zooming the view on screen **20** might have a different k. In other embodiments, k might be varied depending on a different characteristic or condition. For example, k can be proportional to the size of a controlled document (e.g., in bytes), so that a large document may be associated with a higher k and allow the user to easily control a higher speed of scrolling text. Likewise, a smaller-sized document may be associated with a smaller k and allow the user to more finely control the speed of scrolling. The detail or zoom level in a viewscreen might also determine a panning k; e.g., if a view displayed on the screen is a large zoom-out, showing little detail, then the panning rate can be made more coarse using a larger k. If the view is more detailed with a close zoom-in, the panning rate can be made more fine using a small k.

In other embodiments, different relationships or formulas can be used to determine the magnitude of the restoring force (or another type of force instead of a restoring force, if desired). For example, a damping force might be used instead of or in addition to a spring force for different types of objects, isometric functions, or modes. A friction force might be added to the restoring force of equation (1) for further effect, and/or an inertia force.

The direction of the deviation, as mentioned above in step **486**, may also be used to provide different magnitudes of restoring forces. For example, k can be made different in different directions, e.g., +k can be different than −k in a degree of freedom such that it is much harder to push puck **22** forward than to pull it back. The direction of the deviation can also determine if the restoring force is to be applied or not. For example, in the second graphical object embodiment as shown in FIG. **10**, the restoring force is only applied when the direction of the deviation is a direction toward the surface **358**. If the deviation direction is away from the surface **358**, then no restoring force is applied, since isometric mode has not been utilized by moving the cursor into the "isometric surface." In some button embodiments, the direction of the deviation might not affect whether the restoring force is applied or not. Also, in an alternate embodiment, the direction of the deviation can affect the magnitude of the restoring force. For example, if the deviation direction is approximately perpendicular to a surface **358** in FIG. **10** as shown by arrow **496**, the maximum